**Industry Day**

# InSPIRE

## International Space Station SPHERES Integrated Research Experiments

Paul Eremenko
Tactical Technology Office
Defense Advanced Research Projects Agency

(571) 218-4889
paul.eremenko@darpa.mil

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# Agenda

0830-0900 **DARPA and TTO Overview**
*David Neyland, Office Director, DARPA/TTO*

0900-0930 **InSPIRE Program**
*Paul Eremenko, Program Manager, DARPA/TTO*

*0930-1000* **ISS National Lab**
*Jason Crusan, Program Manager, NASA/Space Ops Mission Directorate*

*1000-1015* **Break**

*1015-1115* **Existing SPHERES Infrastructure & Operations**
*Dr. Javier de Luis, Chief Scientist, Aurora Flight Sciences*
*Dr. Alvar Saenz-Otero, Research Scientist, MIT Space Systems Lab*

*1115-1215* **STP Services and Processes**
*Lt Matthew Gartmann, DoD Human Space Flight Payloads Officer, STP*

*1215-1315* **Lunch**

*1315-1345* **ITAR and Security Considerations**
*David Ruebsamen, Int'l Cooperation & Int'l Security Manager, DARPA/SID*

*1345-1415* **DARPA BAA Process**
*Christopher Glista, Contracting Officer, DARPA/CMO*

*1415-1445* **Q&A Session**

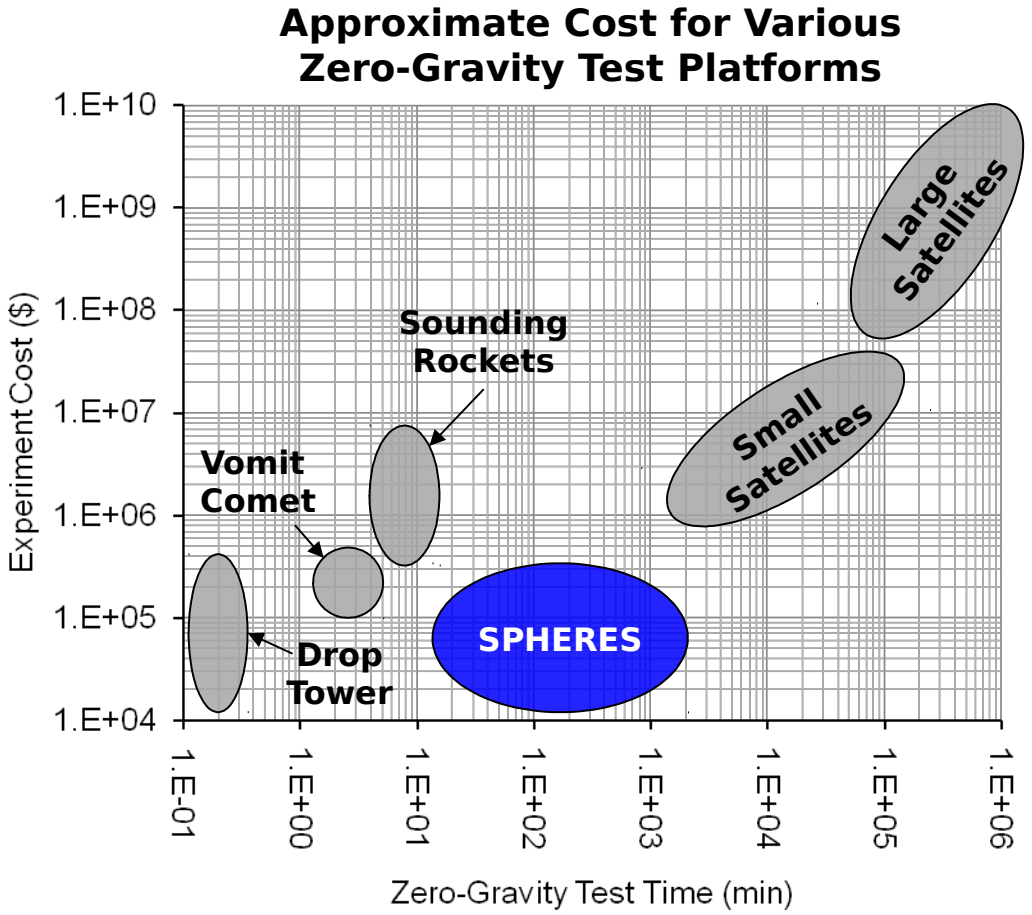
*1445-1545* **Vendor Presentations (5)**

# Industry Day ground rules

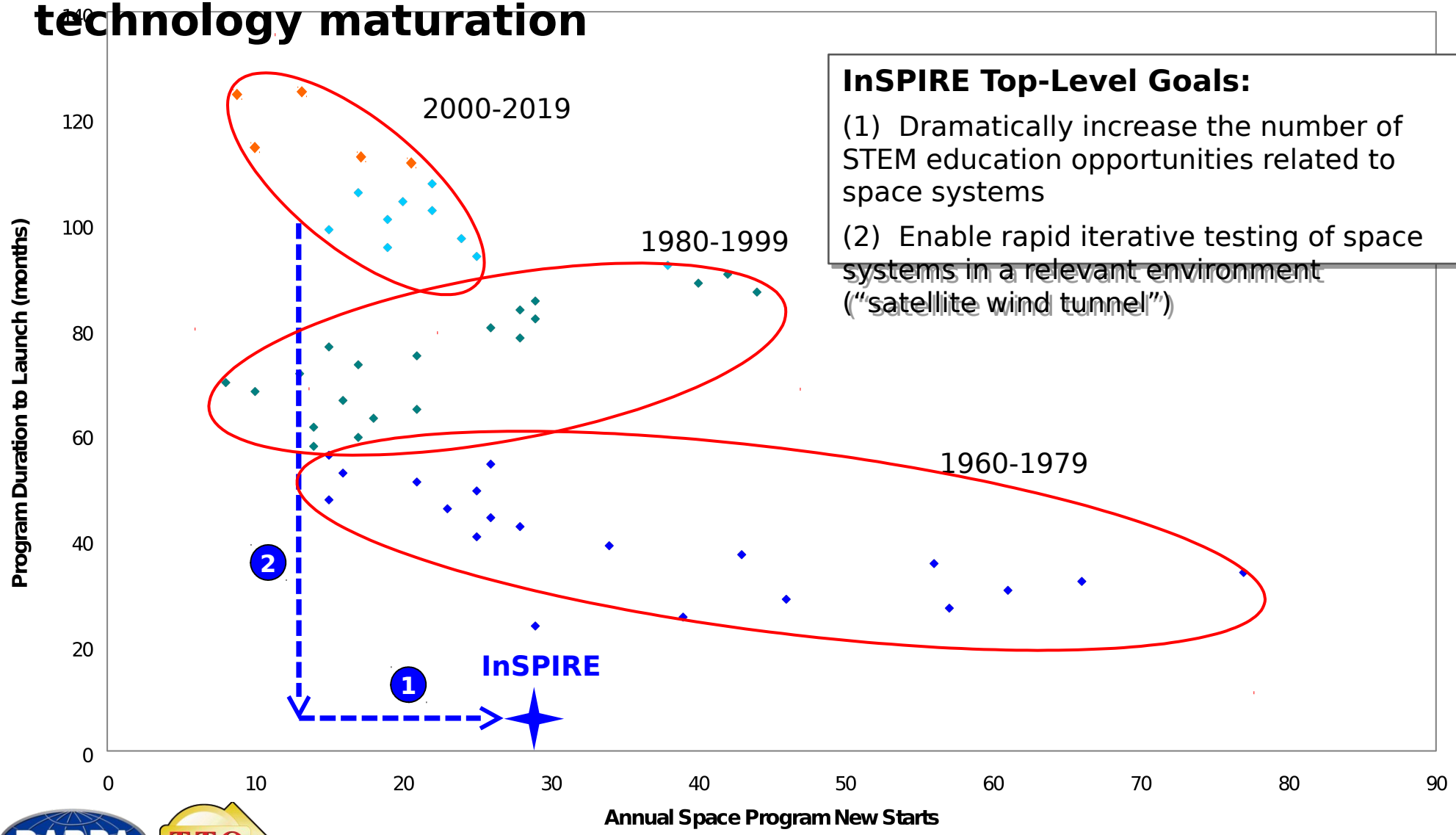
- PM does not have the authority to bind the U.S. Government—only a warranted CO does
- The goal of Industry Day is to articulate DARPA's high-level objectives and solicit your input
  - Provide input during the Q&A/discussion session
  - By e-mail directly to the Program Manager
- The text of the BAA will supersede anything presented or said at Industry Day
- This event is being video recorded and will be posted online
- There are foreign nationals in the audience

# SPHERES is a medium-duration zero-gravity multi-satellite testbed flying on ISS developed by MIT students with DARPA sponsorship

- DARPA-sponsored experiment on the International Space Station since 2006
  - Three small satellites with cold-gas thrusters and ultrasonic GPS simulation now operating in Kibo
  - Developed and prototyped by two generations of MIT undergraduate design classes
  - Principally employed to date as a formation flying algorithm testbed for graduate student research
- SPHERES occupies a unique niche as a medium-duration 0-g testbed capable of rapid design iteration
  - Terrestrial testing (flat floor) allows at most 3DOF
  - 3DOF to 6DOF usually a non-trivial, high-risk step
  - Other test methods are expensive and "one shot"
- SPHERES has "graduated" a significant number of students – with a noticeable industry impact
  - 9 PhDs & post-docs (includes 4 current)



# InSPIRE is a suite of SPHERES experiments aimed at STEM workforce development and rapid iterative testing for technology maturation




**InSPIRE Top-Level Goals:**

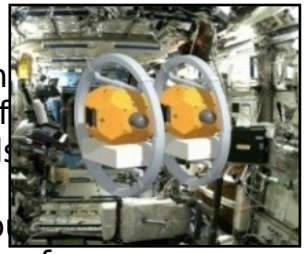
(1) Dramatically increase the number of STEM education opportunities related to space systems

(2) Enable rapid iterative testing of space systems in a relevant environment ("satellite wind tunnel")

DARPA TTO Tactical Technology Office

# Elements of the InSPIRE program

### Electromagnetic Formation Flying / Inductive Power Transfer



- **Objective:** Mature technologies for rem station-keeping and wireless power transf
- **Approach:** Deploy electromagnetic coils and power supply on two SPHERES to:
  - Perform relative station-keeping thro electromagnetic force and torque transfer
  - Perform non-radiative power transfer through resonant inductive coupling
- **Utility:** Raise the TRL on two high-payoff space technologies
  - Significant improvements in station-keeping ΔV for long-duration formation flight
  - Sharing of power resources among multiple space assets

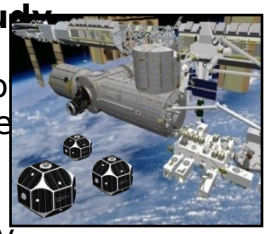
### DARPA SPHERES Challenge

- **Objective:** Create a competition for high school students to develop algorithms to solve challenging problems
- **Approach**: Promulgate a DARPA challenge analogous to prior DARPA challe and FIRST Robotics employing SPHERES:
  - Tiered competitions at local, regional, state, etc. levels in simulation
  - Final competition utilizing real SPHERES on ISS
  - Design of hardware kit for future competition phases
- **Utility:** Develop cadre of future aerospace professionals in order to build up aerospace engineering human resource base

### Cooperative Inspection

- **Objective:** Utilize multiple SPHERES to perform vision-based relative navigation and target mapping
- **Approach:** Develop precision relative navigation capability between two SPHERES
  - Precision timing
  - Micro inertial sensors
  - Vision-augmented navigation sensors
- **Utility:** Rapid development of an entirely novel navigation/prox-ops capability; zero-g testing of new miniature components

### Exo-SPHERES Design Study



- **Objective:** Design and terrestrially proto the next generation of the SPHERES testbe
- **Approach:** In the course of a year long undergrad design-build-test project:
  - Design a short-duration, high-ΔV, very safe platform for near-ISS experiments
  - Build a flat-floor prototype
- **Utility:** Expose a large number of undergraduate and graduate students to a fast-paced spacecraft design project
  - Greatly leverage human presence in space to enable rapid design iteration for development of next-gen space systems

# Electromagnetic Formation Flying & Power Transfer Experiment

## Milestones

- **System Requirement Review**
  - Refine system performance requirements from the proposal
  - Arrive at detailed quantitative system-level performance targets in consultation with the government
- **Preliminary Design Review**
  - Schematic drawings (structural/electrical) of key elements of proposed system
  - Detailed system-level approach
  - Work breakdown structure
  - All information presented in detailed deliverable report
- **HIL-1**
  - Breadboard level system verification
  - Demo software algorithms
  - Show viability of attitude/position control using EMFF
  - Demo power transfer will meet expected power transfer efficiencies
- **HIL-2**
  - Terrestrial testing (i.e., flatfloor) of flight-ready hardware and algorithms, meeting all requirements in 3 DOF
  - Ability to demo 3-DOF attitude/position control using steerable magnetic dipoles
  - Ability to demo the expected power transfer

## Milestones (cont'd)

- **Phase Safety Review**
  - Demonstrate algorithms and hardware meet NASA safety requirements
- **Launch Readiness Date -** June 2011
  - All flight hardware is ready for launch and SPHERES software is ready for uplink
  - Detailed test session plan/schedule is finalized including real time support
- **ISS Demonstration**
  - Ability to demo 6-DOF attitude/position control using steerable magnetic dipoles
  - Ability to demo wireless power transfer in ISS at transfer efficiencies and distances derived in SRR
  - Final technical report delivered after ISS demo which captures accomplishments of this program element

**Award Value: Up to $1 million**

# Cooperative Inspection Experiment

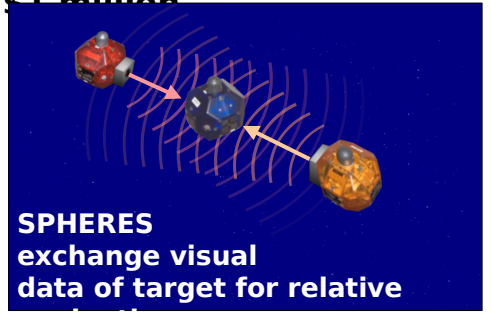
## Milestones

- **System Requirement Review**
  - Refine system performance requirements from the proposal
  - Arrive at detailed quantitative system-level performance targets in consultation with the government
- **Preliminary Design Review**
  - Schematic drawings (structural/electrical) of key elements of proposed system
  - Detailed system-level approach
  - Work breakdown structure
  - All information presented in detailed deliverable report
- **HIL-1**
  - Breadboard level system verification
  - Demo software algorithms
  - Show visual sensor is capable of mapping a target object and accuracy of position/attitude knowledge
- **HIL-2**
  - Terrestrial testing (i.e., flatfloor) of flight-ready hardware and algorithms, in 3 DOF
  - Ability to demo target mapping of an object using 3 DOF control
  - Ability for two SPHERES to perform 3 DOF relative navigation without line of sight using

## Milestones (cont'd)

- **Phase Safety Review**
  - Demonstrate algorithms and hardware meet NASA safety requirements
- **Launch Readiness Date** – June 2011
  - All flight hardware is ready for launch and SPHERES software is ready for uplink
  - Detailed test session plan/schedule is finalized including real time support
- **ISS Demonstration**
  - Ability for two SPHERES to independently map a target SPHERE using visual sensor
  - Ability for two SPHERES to perform relative navigation without line-of-sight using photoregistration of previously mapped SPHERE
  - Final technical report delivered after ISS demo which captures accomplishments of this program element

**Award Value: Up to $1 million**

# Exo-SPHERES Design and Prototype

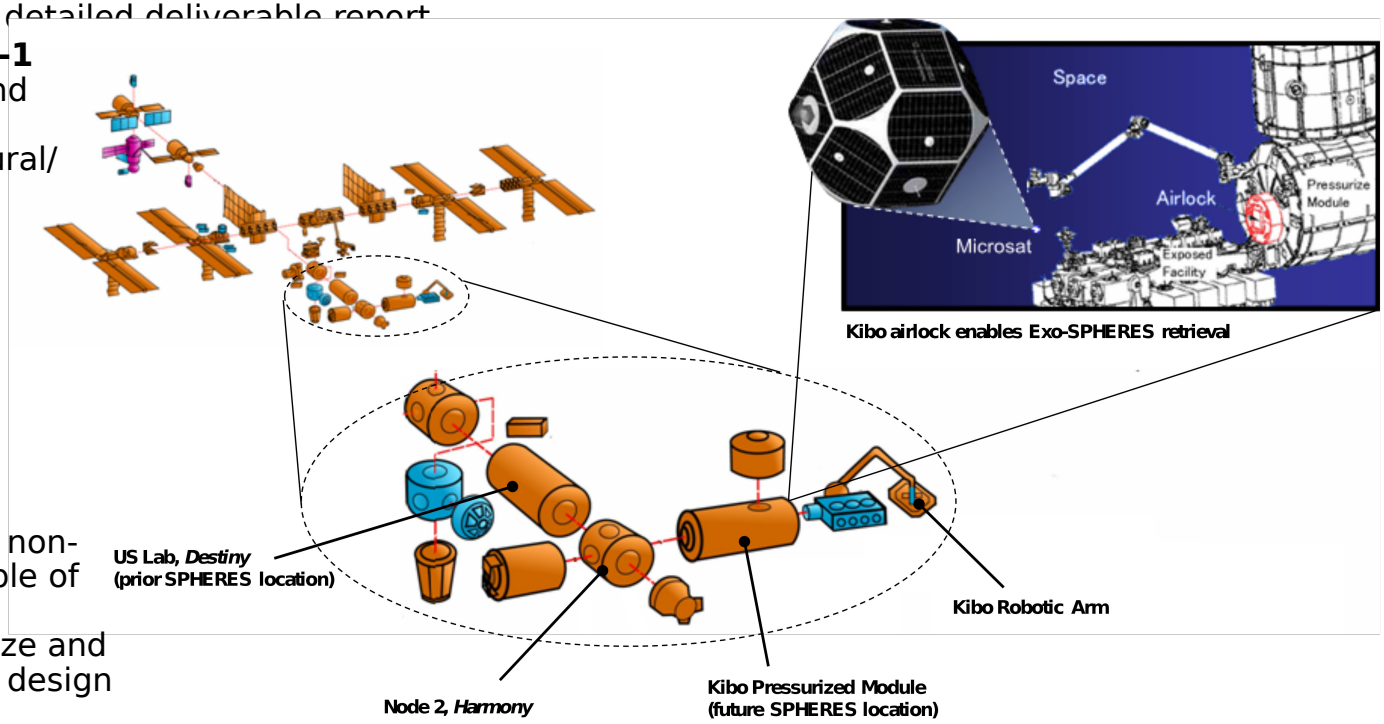
## Milestones

- **System Requirement Review**
  - Refine system performance requirements from the proposal
  - Arrive at detailed quantitative system-level performance targets in consultation with the government

- **Preliminary Design Review**
  - Schematic drawings (structural/electrical) of key elements of proposed system
  - Detailed system-level approach
  - Work breakdown structure
  - All information presented in detailed deliverable report

- **Critical Design Review / HIL-1**
  - Detailed design complete and documented
  - Schematic drawings (structural/ electrical) of all elements of proposed system
  - Breadboard level system verification
  - Demo software algorithms complete
  - All information presented in detailed deliverable report

- **Prototype Completion**
  - Integration and assembly of non-space rated prototype capable of exhaustive ground testing
  - Prototype is characteristic size and shape of proposed full-scale design




**Award Value:** **Up to $750k**

# DARPA SPHERES Challenge

## Milestones

- **Competition Review**
  - Present detailed s/w competition structure including: advertising strategy, detailed game structure, project schedule & budget
  - Competition must be age appropriate and reach out to high schools across the nation
  - Present a design concept of a unique hardware competition kit for next-gen SPHERES competition
- **NASA Phase Safety Review**
  - Demonstrate game algorithms will meet NASA safety requirements
- **Competition Announcement**
  - Advertise competition on a national scale
  - Launch website containing all necessary information needed to participate, including simulator
  - Simulator will enable students to easily verify algorithms and conduct their own internal dry runs
  - Creation of web forum for participants to collaborate
- **Hardware Kit Design Review (not on critical path)**
  - Provide a detailed design of h/w competition kit and cost projection of full scale system
  - Present a SPHERES-based competition using the proposed hardware kit

## Milestones (cont'd)

- **Announcement of Competition Winners**
  - Conduct a staged competition comprising regional, state and national rounds (final breakdown TBD based on number of entrants)
  - Judge national winners of a fair and defendable rubric
  - Make an announcement on a national scale
- **Launch Readiness Date** – February 2011
  - SPHERES software is ready for uplink
  - Detailed competition test session plan/schedule is finalized
- **ISS Demonstrations**
  - Conduct competition/tournament onboard ISS while participating students watch via live feed
  - Compose final report summarizing the competition including STEM efficacy, areas for improvement, and suggestions for follow-on competitions
  - Submit a detailed plan of execution for a follow-on h/w kit competition that includes specs for the designed kit

**Award Value: Up to $750k**

# InSPIRE Crowd-Sourcing Activity

- **Program Summary**
  - Open-innovation approach for the development of algorithms for SPHERES
  - Novel, out-of-the-box ideas for involving vast groups of people in algorithm and software development are strongly encouraged
  - Such concepts may involve prize awards, massively-distributed collaborative development, viral campaigns, prediction markets, new ventures, etc.

- **Program Goals**
  - Participation in the innovation process would be open to groups numbering in the hundreds to thousands, to possibly millions of people worldwide
  - Capture the imagination of the general public
  - Stimulate interest in science, technology, engineering, and mathematics—and particularly space

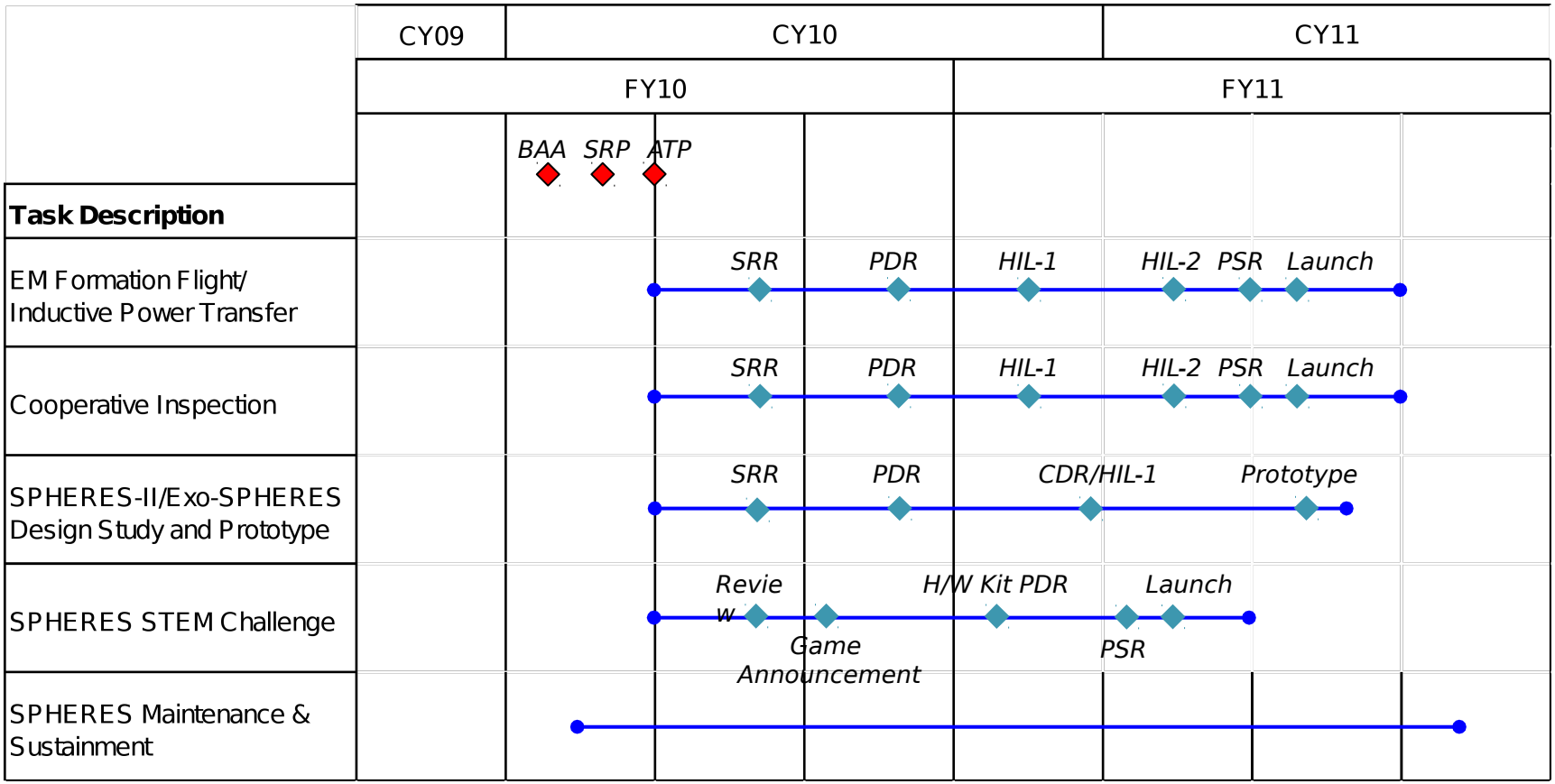
- **Approach**
  - Request for Information (RFI) released Jan. 5 – responses due Feb. 4, 2010
    `https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-SN-10-21/listing.html`
  - Unlikely to be solicited as part of the InSPIRE BAA – may use prize authority instead

- **Previous Successes**
  - DARPA Network Challenge
    - 10 balloons released at different locations across the US
    - $40k prize won by MIT for indentifying coordinates of all 10
    - 58 teams successfully identified location of at least 2 balloons
  - NASA Open Innovation
    - $15k to develop plastics to improve shelf-life of perishable food to 3 years
    - $30k for data-driven forecasting of solar events
    - $20k to develop a compact exercise machine
    - Each challenge has between 150-350 teams competing
  - Netflix Prize
    - $1M prize for best algorithm for user ratings of films
    - 20,000 teams from 150 countries

# Draft BAA scientific review criteria

- **STEM Educational Impact**
  - Breadth and depth of proposed student exposure to current, relevant, and appropriate science and engineering problems
  - Likelihood of proposed activities to enhance learning and interest in science, technology, engineering, and mathematics
- **Overall Scientific and Technical Merit**
  - Extent to which the proposed technical approach is feasible, achievable, complete
  - Proposed technical team that has the expertise and experience to accomplish the proposed tasks
  - Extent to which the proposer's concept advances the stated performance objectives of the program
  - Extent to which the concept performance attributes are substantiated
- **Proposer's Capabilities and/or Related Experience**
  - Proposer's prior experience in similar efforts demonstrate an ability to deliver products that meet objectives
  - Proposed team has the expertise to manage the cost and schedule
- **Potential Contribution and Relevance to the DARPA Mission**
  - Extent contributions of the proposed effort with relevance to the national technology base will be evaluated
  - *Note: DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their application.*
- **Cost Realism**
  - Extent to which proposed cost information is complete, substantiated, and realistic for the approach offered

# Notional InSPIRE program schedule




*SRR: System Requirements Review*

*PSR: NASA Phase Safety Review*

# Miscellaneous closing notes

- Video recording of this event will be posted to the InSPIRE program homepage
  - http://www.darpa.mil/tto/programs/inspire/index.html
- Roles and responsibilities
  - DARPA will be the BAA issuer and exercise technical oversight
  - NASA HQ will be the contracting agent and support the technical oversight role
  - DoD Space Test Program (STP) will provide safety oversight, manifesting, and crew time
  - MIT and Aurora will provide sustainment and operations support for the existing SPHERES
- InSPIRE is funded entirely with 6.2 PE dollars
  - No pre-publication review will be required for work performed on a university campus
  - Onus for ITAR compliance is still with the proposer—more on this from DARPA/SID